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Effect of Tapioca and Guar Gum-Based Edible Coating on Quality and Shelf Stability of Carrots (*Dacus Carota*) at Refrigeration Temperature

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In recent years, the use of edible coatings has emerged as an innovative, efficient, and eco-friendly alternative for enhancing the barrier properties of food, thereby maintaining product stability, safety, and quality while delaying deterioration. The present study was designed to investigate the effect of tapioca and guar gum-based edible coatings on the quality and shelf stability of carrots (*Daucus carota*). Due to carrots' perishable nature, they must be stored for longer periods of time to minimize losses for both domestic and commercial consumption. The tapioca powder was subjected to different functional analyses. Eight treatments were developed by using various concentrations of tapioca, guar gum, and CMC. Treatment combinations were To^- (Uncoated), To^+ = (3% CMC), T_1 = (1% GG, 2% tapioca), T_2 = (0.75% GG, 2.25% tapioca), T_3 = (0.5 % GG, 2.50 % tapioca), T_4 = (0.25 % GG, 2.75 % tapioca), T_5 = (3% tapioca), and T_6 = (3% GG) to investigate the physico-chemical and sensory parameters of carrots during 48 days of storage at 4ºC. The findings indicated that results for foaming capacity, viscosity, water holding capacity, and oil holding capacity of tapioca were significant. With the passage of time, a significant decrease in weight loss and decay percentage was observed in T_4, followed by T_2. Decreased pH and an increase in titratable acidity were also observed in T_4, followed by T_2. Coated carrots maintained their firmness compared to the uncoated ones. The highest firmness results were shown by T_4, followed by T_2. The antioxidants and phenolic contents were decreased as the storage period progressed. Minimum change in anti-oxidants and phenolic content values was observed in T_4, followed by T_2. Sensory analysis results showed that T_4, followed by T_2, were given high scores for color, texture, taste, flavor, and overall acceptability, as compared to other treatments. The study revealed that T_4 followed by T_2 showed effective edible coating formulations in retaining quality and shelf stability of carrots during storage at refrigeration temperature.

Keywords: Edible coatings, Tapioca Powder, Physicochemical and quality characteristics, Sensory analysis, Storage study.

INTRODUCTION

In recent years, consumer demand for healthy, fresh products has risen. In the field of food quality and safety, research on fresh food preservation technology has become more important due to the sharp rise in consumer demand for fresh food in recent years (Sani et al., 2023). Fruits and vegetables are in abundant demand these days due to their nutritious value. Because they are perishable, fruits and vegetables have selective shelf stability. Insects, microbes, and pre- and post-harvest conditions during shipping and preservation can damage or terminate around 30% of fruits and vegetables. The preservation of fruits and vegetables is a main global concern (Raghav et al., 2016).

The consumption of fresh fruits and vegetables is well recognized for its beneficial effects on human health. Carrots exhibit a relatively high perishability. Depending on the nutrient, genotype, physical damage, temperature, and storage conditions, substantial losses of vitamins and other phytonutrients may occur during post-harvest handling and storage. It becomes considerably more challenging to maintain the general quality of veggies. Carrots were therefore preserved in order to get around all of these issues and store them for a longer period of time (Mirani et al., 2022).

Carrots (*Daucus carota*), a root vegetable belonging to the Apiaceae family, are widely cultivated as a cool-season crop. In Pakistan, carrot production reaches approximately 0.22 million tons annually, ranking it as the third-largest vegetable crop in the country. Carrots contains a diverse range of phytochemicals including carotenoids, anthocyanins, and various other phenolic compounds (Jaiswal et al., 2020). The

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three most prevalent antioxidants in carrots are anthocyanin, vitamin E, α- and β-carotene. According to new research, carrot extracts have hepatoprotective and cardio-protective qualities; can lower the risk of Alzheimer's and other dementias, and have antibacterial and antifungal, anti-inflammatory, and analgesic effects as well as reproductive advantages (Riaz et al., 2022). To preserve the freshness and prolong the shelf stability of delicate goods, the food industry has employed various preservation procedures. Due to several biological modifications that reduce their lifespan, carrots deteriorate quickly during storage, which limits their commercial potential (Mastromatteo et al., 2012).

A coating can be defined as a thin-layered structure composed of a biopolymer. Edible coatings refer to those made from food-grade ingredients and are non-toxic for human consumption. It is measured as a suitable approach to ensure food safety and to extend the shelf stability (Yousaf et al., 2022). Enhancing food emergence and providing food protection due to its environmentally friendly nature are the main goals of edible coating. Both plant and animal sources can provide the coating's substance (Sharma et al., 2019). Edible coatings and edible films are the two principal classes of edible packaging materials. It offers many benefits, comprising antibacterial qualities, oxygen and ethylene scavenging abilities, and moisture barrier functions. Edible coatings can be applied to food items in a diversity of ways, such as layer by layer, dipping, spraying, and brushing (Oduro et al., 2021).

Tapioca starch offers the widest range of uses in the food industry. Tapioca starch, both natural and modified, has found widespread use as a food ingredient. Tapioca starch is typically used as a stabilizer and thickener in culinary applications. Compared to other amylose-containing starches, tapioca starch has a lower amylose percentage, a large molecular mass of amylose and amylopectin, and a small amount of residual elements (Breuninger et al., 2009).

According to Ronie et al. (2025), there are a lot of promising prospects for future uses in the food sector with tapioca flour and starch. Several studies show that tapioca flour works well as a gluten substitute, enhancing the overall quality, texture, and moisture retention of gluten-free products. Tapioca's adaptability in a range of food applications is highlighted by its considerable thickening abilities and assistance in transforming the texture of food products. Whittington et al. (2025) claimed that tapioca is low in salt and saturated fat and has trace levels of potassium; it may help control blood pressure and lower the risk of heart disease. Tapioca may be a better substitute for wheat- or corn-based products because it is naturally free of grains and gluten. For instance, it can be used as a thickener in broths and sauces, or as a flour in baking and food preparation. Cassava root is an energy-dense food. In this regard, cassava shows very efficient carbohydrate production per hectare. Tapioca contains carbohydrates, lipids, proteins, and amino acids. It also contains a considerable amount of minerals and vitamins, including iron, magnesium, copper, zinc, potassium, and vitamins C & B (Montagnac et al., 2009).

The food industry uses tapioca for many purposes, but it is rarely used in edible coatings. However, the powder's functional qualities make it appealing enough to use for coating fresh goods. Tapioca was used in several earlier investigations to create coatings, as was previously reported. Consequently, the goal of this study is to develop an edible coating based on tapioca powder for processing and preserving carrots, and to investigate how these coatings affect carrot physicochemical properties, qualitative features, and shelf stability.

MATERIALS AND METHODS

***Selection of raw material*:** Samples of carrots were collected at the Sargodha local market in Punjab province. Carrots that were fully matured, uniform in size, shape, and color, and free of blemishes, cuts, bruises, and pathogenic and fungal infections, and retained their stems were selected. In the microbiology lab, carrots were manually sorted and graded. While all of the chemicals were gathered from Sigma Chemicals Co., USA, other raw materials, such as glycerol, guar gum, oil, and plastic bottles, were procured from Metro Cash & Carry.

***Preparation of tapioca powder*:** Tapioca pearls were taken from the market then proper cleaning of tapioca pearls was done to remove debris and unwanted particles from them. Then grinding of tapioca seeds was done to make fine powder. The powder was then stored in zip-lock bags after being sieved using U.S. Standard sieves, approximately number 170-200 (Endecotts, London, UK) to produce a particle size of 80µm. When making the powder, instructions were drived from the previous investigation of Singh et al. (2008).

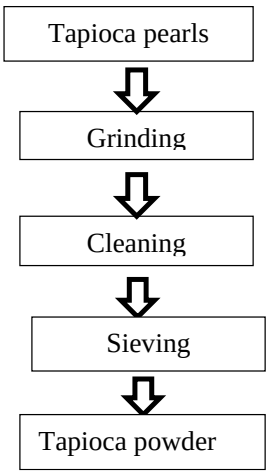

Figure 1. Production of tapioca powder (Singh et al., 2008).

Proximate analysis of tapioca powder: In accordance with the standard procedures of the Association of Official Analytical Chemistry (AOAC), a proximate analysis of tapioca powder, such as moisture, ash, crude fiber, protein and fat content, was conducted by AOAC (2019). However, as shown below, nitrogen-free extract (NFE) was computed by deducting the sum of all parameters from 100.

NFE (%) = 100 –

(moisture% + ash% + crude protein% + Crude fat %)

FUNCTIONAL ANALYSIS OF TAPIOCA POWDER

***Foaming capacity*:** The method described by Akhter et al. (2019) was used to measure the foaming capability of tapioca powder. In short, 100 mL of distilled water was combined with 3 g of tapioca powder, and the mixture was mixed for 3 minutes at high speed in a food mixer. Before and after mixing, the mixture's volume changed. By using the formula, the foaming capability of tapioca powder was determined.

$$\text{Foaming capacity} = \frac{V_2 - V_1}{V_1} \times 100$$

The volumes of the solution before and after mixing are denoted by V_1 and V_2, respectively.

***Viscosity*:** The viscosity of the emulsions was determined after cooling the samples at 4 °C. The viscosity of the samples was measured using a Lamy Rheology Instruments rotator-type viscometer with minor adjustments. Siddique et al. (2024) method was used to measure the material's approximate viscosity. Spindle number five was used to measure the viscosity, and the instrument's speed was set to 50 rpm.

***Water holding capacity*:** Water holding capacities (WHC) of tapioca powder without heating (W_1) and with heating (W_2) were calculated by using the Hussain et al. (2023) technique with minor modifications.10 milliliters of distilled water were added to each of two beakers containing one gram of tapioca powder to test the water-holding capacity. For over fifteen minutes, one beaker was heated to 150°C on a hot plate while being stirred. Following that, the contents of both beakers were transferred into centrifuge tubes that had already been weighed, and they were vortexed for ten minutes each. These tubes were then centrifuged for 15 minutes at 1000 rpm using a Hettich Zentrifugen (ROTINA 380R, Germany). The excess water from the tube was removed, and the wet weight of the remaining material was measured along with the centrifuge tube. The temperature (150 °C, 15 min) was selected as a mild dry-heat treatment to alter functional properties without inducing thermal decomposition. The WHC was calculated by the formula given below;

Water holding capacity (%) =

$$\frac{\text{Wet sample weight} - \text{Dry sample weight}}{\text{Dry sample weight}}$$

***Oil holding capacity*:** The oil holding capacity (OHC) of tapioca powder was measured using the Hussain et al. (2023) method, both with and without heating (W_1 and W_2). In short, 10 mL of oil was added to each of the two beakers containing 1 g of tapioca powder. One beaker was heated to 150 °C for over 15 minutes on a hot plate while being stirred. After that, test tubes containing these oil solutions were vortexed for ten minutes. After that, centrifugation was carried out for 15 minutes at 1000 rpm. The following formula was used to determine the oil holding capacity:

Oil holding capacity (%) =

$$\frac{\text{wet sample weight} - \text{Dry sample weight}}{\text{Dry sample weight}}$$

***Preparation of edible coating*:** With slight adjustments, the Gull et al. (2021) procedure was used to create the edible coating. Tapioca powder was combined with distilled water at a 1% w/v ratio. Guar gum and carboxymethyl cellulose (CMC) were added, and different emulsions were made by heating them to 150 °C for seven minutes after magnetic stirring for one hour at 40 °C. Following room temperature cooling, 100 mL of emulsion was mixed with 5 mL of olive oil and 2 mL of glycerin as a plasticizer. At 40% amplitude, sonication was performed with a probe-type ultrasonic processor for seven minutes. For 20 minutes, a vortex operating at maximum speed was utilized for homogenization at room temperature (25°C). To remove the air bubbles created during homogenization, the emulsions were allowed to sit at room temperature for 15 minutes. These emulsions were stored in a refrigerator.

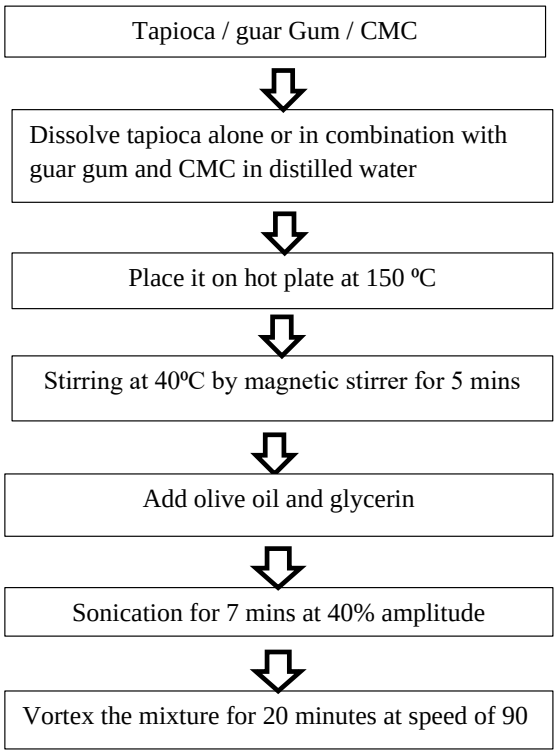
Tapioca / guar Gum / CMC
Dissolve tapioca alone or in combination with guar gum and CMC in distilled water
Place it on hot plate at 150 ºC
Stirring at 40ºC by magnetic stirrer for 5 mins
Add olive oil and glycerin
Sonication for 7 mins at 40% amplitude
Vortex the mixture for 20 minutes at speed of 90

Figure 2.Preparation of coating emulsion (Gull et al., 2021).

Table 1. Treatment Plan.

Treat.	Guar gum (g)	Tapioca (g)	CMC (g)	Glycerin (mL)	Olive oil (mL)
T_0^-	-	-	-	-	-
T_0^+	-	-	3	2	5
T_1	1	2	-	2	5
T_2	0.75	2.25	-	2	5
T_3	0.5	2.50	-	2	5
T_4	0.25	2.75	-	2	5
T_5	-	3	-	2	5
T_6	3	-	-	2	5

Application of edible coating: To get rid of any impurities from their surface, the carrots used for the studies were first rinsed with distilled water and then dried with paper towels. The brushing technique was employed to enable the carrot's coating to be applied smoothly. After cleaning and drying the carrots, the coating was applied, any surplus material was dripped off, and the carrots were put in baskets to dry for 20 minutes at room temperature (25 ± 5 °C). For 48 days, all of the carrots, coated and uncoated, were stored at 4 ºC in preparation for additional examination. After drying, the coatings appeared transparent and integrated with the carrot surface.

Quality Attributes of Carrots

***Weight loss percentage*:** By using the methodology given by Zakriya et al. (2023), the percentage of weight loss was determined by calculating the difference between the beginning and ending weight of carrots after every 4 days throughout the course of 48 days. Weight loss percentage was determined by the given formula:

$$\text{Weight loss (\%)} = \frac{\text{Wt.of initial} - \text{Wt.of final}}{\text{Wt.of initial}} \times 100$$

***Decay percentage*:** By using the methodology given by Bashir et al. (2023), the percentage of decayed carrots was calculated. The percentage of vegetables with visible microbial contamination and foul was used to determine the decay percentage. Decay percentage was calculated by given formula:

$$\text{Decay \%} = \frac{\text{Number of decayed fruits}}{\text{Number of total fruits}} \times 100$$

***Determination of firmness*:** The firmness was determined by following the approach provided by Thakur et al. (2019). The firmness of the whole carrot treatments was tested across a range of storage times using a texture analyzer (TA-XT2, Stable Micro Systems, UK) equipped with a cylindrical stainless-steel probe measuring 35 mm in diameter. The operational settings used for the firmness measurement were 5 mm/s for the pre- and post-test speeds, 3.0 g for the compression degree, and 10 s times the trigger force. Six exact fruits were selected from each group, and the measurements of each fruit were taken separately. To assess the firmness of each coated carrot, the coatings were physically peeled from two opposing sides.

Determination of juice yield: Juice yield of the sample was calculated by the method given by Booth et al. (1988), where the sample was first weighed on a balance, chopped, and then ground. A juicer was used for juice extraction. Afterward, it was filtered and measured.

$$\text{Juice yield \%} = \frac{\text{weight of extracted juice}}{\text{weight of raw produce}} \times 100$$

***Sensory analysis*:** Sensory evaluation, followed Rafique et al. (2023), was used to determine the sensory parameter scores of various carrot treatments using a nine-point hedonic scale. Thirty semi-trained student panelists (both sexes, mean age 23 years, University of Sargodha) provided informed consent and were briefed on the study. Panelists scored color, texture, taste, flavor, and overall acceptability for each carrot treatment.

PHYSICO-CHEMICAL ANALYSIS OF CARROTS

Total soluble solids (TSS): By following the procedure described by Zakriya et al. (2023), the TSS of several carrot samples were measured using a digital refractometer (RHB-32 ATC model, China), and the results were recorded as Brix.

Determination of pH: Carrots' pH was measured using a digital pH meter (Elico Model LI 120, Hungary) in accordance with the AOAC (2019) method no. 981.12. After being rinsed with distilled water and dried with tissue paper, the pH meter rod was submerged in a sample of carrot puree for 30 to 40 seconds. Each computation was performed three times to obtain the mean values.

Titratable acidity: In accordance with AOAC (2019) standard method no 942.15, the carrot juice sample was diluted and titrated against a 0.1 N NaOH solution with a few drops of phenolphthalein indicator until it became pink in order to measure the titratable acidity of carrots. NaOH values were then recorded. The following formula was used to determine titratable acidity; each trial was carried out three times, and the results were presented as means.

Titratable acidity (%) =

$$\frac{\text{mL of titrant used} \times \text{N.of titrant} \times 0.064}{\text{Sample Wt.}} \times 100$$

Determination of total phenolic content: *TPC was* determined following Hussain et al. (2023). Carrot extract (0.5 mL) was mixed with 1mL Folin-Ciocalteu reagent, incubated for 5 minutes, then added 2mL sodium bicarbonate was added, and incubated at 30°C for 60 minutes. Absorbance was measured at 760 nm using a Hitachi U-2900 spectrophotometer (Japan) and expressed as µg GAE/g.

***Determination of Anti-oxidant*:** Total antioxidant capacity (TAC) of carrot juice was determined following Cheng et al. (2006). Samples (100 µL) were mixed with 900 µL reagent (28 mM sodium phosphate, 4 mM ammonium molybdate, 0.6 M sulfuric acid), incubated at 95°C for 90 min, cooled, and absorbance measured at 695 nm using a microplate reader. TAC was quantified as µg AAE/100 µL juice via ascorbic acid standard curve (0–100 µg/mL).

Statistical Analysis: Data were subjected to two-way ANOVA (treatment × storage time) using Statistix 8.1 software (Montgomery, 2017). Mean differences were separated using Fisher's Least Square Difference (LSD) test at $p<0.05$ significance level.

RESULT AND DISCUSSION

***Proximate analysis of Tapioca powder*:** The proximate analysis determines the proportion of elements present in food. These are used to determine food's moisture, fat, fiber, protein, ash, and nitrogen-free extract. Table 2 shows the results of the proximate of tapioca powder. Moisture of tapioca powder was 9.75%, ash 0.37%, fiber 0.18%, protein 1.29%, fat 0.19% and NFE was 88.22%.

Table 2. Proximate analysis of tapioca powder (%).

Moisture (%)	9.75 ± 0.02
Ash (%)	0.37 ± 0.02
Fiber (%)	0.18 ± 0.02
Fat (%)	0.19 ± 0.02
Protein (%)	1.29 ± 0.02
NFE (%)	88.22 ± 0.02

The means and standard deviations of the data are displayed (n=3).

A study showed similar results. Where starch from the cassava plant was extracted, and proximate analysis was done. The result showed that the moisture content was 9%, 0.31% ash, 0.20 fiber, 0.17% fat, 1.24% protein, and 88.23% NFE for tapioca (Ijioma et al., 2016).

The ash content ranged between 0.1% and 0.7%, indicating that cassava grown in Tawau, Malaysia, or Semporna is mineral-rich. The total fiber content of tapioca is 2.09% and 2.38% (Rodriguez Sandoval et al., 2008).

Another study revealed the results for the proximate analysis of water chestnut powder. Results showed that water chestnut powder contains 7-8% moisture, 0.04% ash, and 0.21-0.22% protein contents (Kaur et al., 2023. The water chestnut powder's moisture content was 7.26%, lipid content was 0.21%, protein content was 0.24%, fiber content was 0.26%, ash content was 1.72%, and NFE was 90.28% (Mahnoor *et al*., 2024).

Foaming capacity: Foaming capacity is the ability of a gum molecule to reduce surface tension whenever air and water combine to generate foam. When gums are rubbed rapidly, an unbreakable network is formed that absorbs and holds onto tiny gum particles, producing foam. As a result of whisking gums achieving a solid structure, tiny gum particles can produce foam (Ahsan et al., 2024).

Table 3 shows the results of the foaming capacity of tapioca. Another study indicated that the Semporna cassava flour had a higher foaming capacity (7.33%) than Tawau cassava flour (3.66%). Semporna cassava flour has a greater protein level than Tawau, with 2.69% and 2.07% respectively. The results of our study were also supported by these findings (Kaushal et al., 2012).

Viscosity: The viscosity of certain emulsions is described in terms of thickness. Temperature and shear rate can have an impact; the greater the temperature and percentage, the lower the emulsions' viscosity. Regardless of the type of cassava, the viscosity rose as the solid concentration increased (Ahsan et al., 2024). The viscosity of 3g tapioca powder was 3.29mPa.s.

Similarly, Ansari et al. (2017) pointed out that the viscosity of the emulsion was caused by the starch included in water chestnut powder. However, Mei et al. (2013) found that the amount, kind, and processing of starch all affect viscosity. The viscosity varied between 13.627 and 12.666 mPa.s for varying amounts of water chestnut powder and tragacanth gum, according to a study by Kalsoom et al. (2025) on edible coating prepared with these ingredients.

Table 3. Foaming capacity (%) and viscosity (mPa.s) of tapioca powder.

Foaming capacity (%)	Viscosity (mPa.s)
7.36±0.006	3.29±0.008

The means and standard deviations of the data are displayed (n=3).

***Water holding and oil holding capacity*:** The quantity of water that gum or powder can absorb or hold onto is known as its water-holding capacity (WHC). The oil holding capacity (OHC) of a powder is the amount of oil it can hold. While the gum's pore size and charges on the protein molecule affect its ability to hold water, the gum's chemical and structural characteristics primarily govern its ability to hold oil. The structure of polysaccharides is also influenced by the quantity of hydroxyl groups and residual amino acids (Mahnoor et al., 2024).

Table 4 shows the values of water and oil holding capacity of tapioca powder with and without heating. When tapioca powder is heated, its starch network structure increases. So, the value of the water holding capacity of tapioca powder increased by heating from 2.38 to 3.07% as tapioca starch molecules swell by heating. However, oil holding capacity decreased by heating from 2.40 to 1.72%.

Table 4. Water holding capacity and oil holding capacity of tapioca powder (%).

Sample	WHC (%)	OHC (%)
Tapioca (without heating)	2.38±0.01	2.40±0.08
Tapioca (with heating)	3.07±0.01	1.72±0.08

The means and standard deviations of the data are displayed (n=3).

Another study revealed that the ability of cassava flour to absorb water depends on how well the starch molecules aggregate. The rate of water absorption capacity was raised by weak aggregation power between starch molecules, which

made it easier for the molecules' surface to form a bond with water molecules (Aryee et al., 2006).

Quality attributes of carrots

***Weight loss*:** The main reasons of weight loss in vegetables are transpiration and respiration, which affect the fruit's surface loss of water vapor or moisture. Vegetables gradually lose weight as humidity levels drop, leading to several unsuitable changes in vegies' storage time and nutritional content. Vegetables shrink more and produce more when their body weight decreases. By serving as an obstacle between the vegetable and its surroundings, edible coatings primarily aim to reduce transpiration and transpiration rates. Furthermore, edible coating prevents fruits from losing weight (Ali et al., 2020).

It was noticed that treatments have a significant effect on carrots' weight loss. Table 5 shows the result of weight loss. Minimum weight loss was observed in T_4 (5.999%) and T_2 (6.416%). Maximum weight loss was observed in T_0^- (17.84%) during the storage period of 48 days. A study reported that all samples aside from the treated ones showed a drop in weight during storage (Nawab et al., 2017).

A recent study inspected the effects of tapioca and tragacanth-based coatings on tomatoes' weight loss and decay and found several results that significantly supported the current findings (Fatima et al., 2025). An edible coating made of cassava starch and chitosan was applied on mangoes. Mangoes were subjected to nine distinct procedures to determine their eligibility. Mangoes' color, texture, odor, and pace of weight reduction were all preserved in the mixture (Camatari et al., 2017).

***Decay percentage*:** The factors of light, temperature, microbial attack, and moisture often cause fruits and vegetables to rot and decompose. The most common signs of vegies deterioration and spoiling are bruising, color loss, mold and slime patches, defects, and an unpleasant taste and odor. The primary cause of vegies' degradation is moisture loss (Thakur et al., 2019).

Table 5 showed the decay % of carrots minimum decay of carrots was observed in T_4 (2.24%), T_2 (2.56%). Maximum decay of carrots was observed in T_0^- (6.249%) during the storage period of 48 days. A similar study indicated that water chestnut-based edible coatings decreased fruit deterioration. Coatings based on water chestnuts were applied to the tomatoes. The results demonstrated that the coating stopped tomatoes from spoiling by reducing their rate of deterioration (Kalsoom et al., 2025).

An edible coating made of aloe Vera gel was found to be helpful in preventing papaya fruit from rotting compared to uncoated papaya fruits. Freshly cut apples treated with alginate showed lower counts than control samples (Gomes, 2013).

***Firmness*:** Fruit firmness is regarded as a preliminary textural metric. Fruit's flavor is also influenced by firmness. Because they are thought to be of greater quality, people prefer firmer fruits than soft ones. As fruit loses moisture during storage, its hardness falls along with its freshness. The maximum force required to compress a sample to 50% of its initial dimension (% strain) is referred to as a textural property of fruits (Mahnoor et al., 2024).

Table 5 showed that maximum firmness was recorded by T_4 (3067N), T_2 (3065N), and minimum firmness was recorded by T*o*− (3051N) during the course of 48 days. Similar findings from a different study indicated that carrots lose their firmness after being kept in a cold environment for extended periods of time. The lowest mean value for firmness was recorded at the 120th day, which had 2561N firmness at 85% relative humidity, while the maximum mean value was noted at 0 day, which had 3200N of firmness at a similar relative humidity. This study supported our results that firmness decreased with the passage of time (Rashidi et al., 2009).

Another study was conducted to check the firmness of tomatoes coated with water chestnut-based coating. The results demonstrated that there was a reduction in firmness of tomatoes at the 20th day of the storage period (Kalsoom et al., 2025).

***Juice Yield*:** The term "juice yield" refers to the quantity of fruit juice that is extracted, and the quality of the fruit determines it. Juice from high-quality fruit is more abundant, and vice versa. Dried fruits are the result of increased moisture loss during storage, which lowers juice supply (Kalsoom et al., 2025).

The data illustrated that treatments have a considerable effect on carrot juice yield. Table 5 showed the data for the juice yield of carrots. Maximum juice yield was observed by T_4 (105.0%) and T_2 (104.4%). Minimum juice yield was observed by T_0^- (84.692%) during the storage period of 48 days.

Table 5. Overall means for Quality analysis of carrots during storage.

Treat.	Weight loss (%)	Decay percentage	Firmness (N)	Juice Yield (%)
$T0^-$	17.849^{A}	6.249	3051.4^{H}	84.64^{F}
$T0^+$	10.629^{E}	5.768	3055.0^{F}	95.15^{B}
T1	10.238^{F}	6.089	3053.8^{G}	86.10^{E}
T2	6.416^{G}	2.563	3065.4^{B}	104.40^{A}
T3	17.690^{AB}	5.448	3064.4^{C}	89.90^{C}
T4	5.999^{H}	2.243	3067.3^{A}	105.00^{A}
T5	16.471^{D}	4.807	3057.3^{E}	85.30^{F}
T6	16.464^{CD}	5.127	3060.2^{D}	87.40^{D}

Physicochemical analysis:

***pH*:** When *t*he fruit ripens, it produces acid. The acid that is produced can contribute to the fruit's many qualities, including flavor. Acid also enhances the color and quality of fruit juice. Fruit's shelf stability or freshness is also impacted by pH (Hussain et al., 2023).

Carrot's pH level was significantly impacted by treatments.

Table 6 shows the pH of carrot juice. Minimum pH was shown by T_4 (6.202) and T_2 (6.203). Maximum pH was shown by T_0^- (6.321) during the storage period of 48 days. A study showed similar results, reporting that the pH of carrots changed significantly during the course of 19 days of storage. On the 19th day, the pH lowered from 6.60 to 6.39. This indicates that when carrots are coated, their pH value drops. The coated carrots have a lower pH measurement than the uncoated ones. Their results are in accordance with our study that pH fell during storage (Shigematsu et al., 2018).

When an edible coating based on tragacanth was applied to pomegranate fruit, the pomegranate fruit's acidity and pH were decreased as they were preserved by the tragacanth-based coating (Mokhtarizadeh et al., 2020). Apple juice's pH value was lower than that of uncoated apples at the beginning of the storage period, and notable fluctuations were noted because organic acids were used less effectively and the pH dropped (Jahanshahi et al., 2018).

Total soluble solids: Total soluble solids, which are frequently made up of proteins, minerals, and carbohydrates, are defined as the entire amount of solid material in a solution. The degree Brix, or total soluble solids, is calculated using the index of refraction, which is determined using a refractometer (Farooq et al., 2023). Another study illustrated that the TSS of guava fruits by applying edible coating rose to a specific time period as the time period progressed, there was a decrease in TSS of guava fruit (Ainee et al., 2022).

Treatments have a substantial impact on the TSS of carrots. Table 6 shows the results of the TSS of carrots. Minimum TSS was shown by T_4 (8.521 °Brix) and T_2 (8.520 °Brix), and maximum was shown by T_0^- (8.67 °Brix) during the storage interval of 48 days. Another study reported that TSS rises with increasing storage period and that the maximum TSS of 10.6% was observed on the 120th day of storage period, and the lowest 8.63% on a 0-day storage period of carrots (Rashidi et al., 2009).

Titratable Acidity: Titratable acidity is the term used to describe the amount of acid in food. A food's overall acidity is determined by comparing an acid to an average base. When assessing how acid affects fruit flavor, this method is more precise than pH. Because of a decline in the acid value produced by substrate utilization, acidity levels typically rise after harvest and fall during the ripening phase (Zakriya et al., 2023).

It was noticed that both treatment and storage significantly affect the acidity of carrot juice. Table 6 showed that maximum acidity was shown by T_4 (0.248%) and T_2 (0.246%), and minimum was recorded by T_0 (0.239%) during the storage study of 48 days. It was noted that carrots' titratable acidity rises over time. Carrots' titratable acidity levels fall between 0.17 to 0.28%. As time goes on, this acidity gets more intense (Sharma et al., 2009).

Anti-oxidant: Antioxidants are substances that help prevent and delay certain types of cell damage. Antioxidants are abundant in fruits and vegetables. Antioxidants reduce the risk of disease by scavenging free radicals, which are the source of oxidative stress. The overall antioxidant capacity can also be estimated by counting the number of free radicals that the solution scavenges (Kalsoom et al., 2025). It was noticed that treatments significantly affect the antioxidant level of carrots. Table 6 shows the results of the carrot's antioxidant level. Minimum anti-oxidant value was shown by T_4 (16.07μg/g) and T_2 (16.08μg/g) and maximum value was shown by T_0^- (16.17μg/g). Another study showed the same approach demonstrated that the antioxidant of carrots varies from 16.50μg/g/g to 11.07μg/g on 0 day to 24th day, respectively. This indicates that refrigerated storage reduced the antioxidant level of carrots. Our results are closely relevant to that study (Haq et al., 2017). Studies on the effects of Arabic gum as an edible coating have also revealed that edible coating assisted in keeping and maintaining the lycopene content and overall antioxidant capacity (Ali et al., 2013).

Phenolic content: Total phenols are an important part of plants that regulate antioxidant activity. The polymeric secondary metabolites of the phenolic substance are present in food. They aid in the detoxification of plant-based free radicals. The amount of phenolic content in food is commonly ascertained by measuring the activity of the total phenolic content (Hussain et al., 2023).

Treatments significantly affect the carrot's phenolic content. Table 6 shows the results of the phenolic content of carrots. Minimum phenolic content was shown by T_4 (39.61mg GAE/g) and T_2 (39.63mg GAE/g), and the maximum value was shown by T_0 (40.22mg GAE/g).

The phenolic content was decreased over time. The phenolic content of carrots decreased by 41.63mg GAE/g to 32.31mg GAE/g during 24 days of storage of carrots at refrigeration temperature. Their values are closely related to our study (Haq et al., 2017). It has been indicated that the edible coating can retain the total phenolic content, which is affected by the drying process used to preserve fruits and vegetables (Salehi et al., 2023).

Table 6. Overall means for physicochemical analysis of carrots during storage.

Treat.	pH	TSS (ºBrix)	TA (%)	Anti-oxidant µg/g	Phenolic Content (mg GAE/g)
$T0^-$	6.321^A	8.676^A	8.676^A	16.172^A	40.226^A
$T0^+$	6.299^B	8.677^A	8.675^A	16.153^D	40.208^B
T1	6.279^C	8.617^C	8.617^C	16.108^F	40.118^E
T2	6.203^F	8.565^E	8.520^E	16.084^G	39.635^G
T3	6.224^D	8.562^D	8.562^D	16.168^B	40.073^F
T4	6.202^F	8.521^E	8.521^E	16.079^H	39.612^H
T5	6.219^E	8.645^B	8.645^B	16.162^C	40.173^C
T6	6.226^D	8.520^D	8.565^D	16.126^E	40.126^D

***Sensory Analysis*:** The sensory analysis of carrots was done by trained people. It was observed that there are differences in coated carrots comparable to uncoated carrots. Different parameter of sensory analysis was done during the whole storage period.

***Color*:** Color is a very important factor for consumer acceptance. Bright and fresh colors can attract consumers. During the 48-day storage study of carrots, it was observed that coated carrots showed less color loss compared to uncoated carrots. During 1st 15 days, it was observed that there is less damage to the color. In the next 15 days, there was little change in the color of coated carrots except T_4 followed by T_2. In the remaining days color of T_4 followed by T_2 was much stable than other coated and uncoated carrots.

More satisfactory results were achieved by coated carrots, prominently by T_4, followed by T_2. In my storage study, most of the people gave high scores to the color of coated carrots of treatment T_4, followed by T_2. Both these treatments provide the best results in color retention. Similar outcomes were shown by (Lai et al., 2013).

When aloe vera gel and a few additional components were applied to Fuji apples, the coating caused a delay in color change and a notable reduction in the greasiness of the coated fruits (Farina et al., 2020). The results of a related study on apples that applied a polysaccharide-based coating derived from seeds (fenugreek and flax seeds) revealed that the coatings increased the vegetable's color and prolonged their shelf life (Rashid et al., 2020).

***Flavor*:** The chemical senses of taste and smell are both part of the sensory perception known as flavor. Foodstuffs are chosen, accepted, and consumed with the help of flavor. Food flavor can be altered while maintaining a pleasing taste by altering the food's aroma. It was observed that treatment has a significant effect on the flavor of carrots (Rafique et al., 2023).

During the 48-day storage study of carrots, it was observed that coated carrots showed less flavor loss compared to uncoated carrots. During 1st 15 days, it was observed that there is less loss in flavor. In the next 15 days, there was little change in the flavor of coated carrots, except for T_4 followed by T_2. After that, in the remaining days flavor of T4 was much stable, followed by T_2, that the other coated and uncoated carrots. The maximum score regarding the flavor was gained by T_4, followed by T_2. Both these treatments showed significant results for the flavor of carrots. T_0^- showed great flavor change during storage. The results of an edible coating made of chitosan on strawberries were comparable. The distinctive flavor and taste of strawberry fruits were shown to be retained by the edible coating. The high flavor score of tapioca guar gum-coated carrots was due preservation of the volatile compound due to the coating's barrier properties (Riaz et al., 2021).

***Taste*:** Flavor is perceived when flavor stimuli get to the taste receptors. Taste is stimulated by taste buds in the oral cavity and on the tongue. The basic tastes are umami, bitter, salty, sour, and sweet. It was observed that coated carrots show great taste compared to the uncoated carrots. During the 48-day storage study of carrots, it was observed that coated carrots showed less taste change compared to uncoated carrots. During 1st 15 days, it was observed that there is less change in taste. In the next 15 days, there was little change in the taste of coated carrots, except T_4 followed by T_2. After that, in the remaining days taste of T_4 was much stable, followed by T_2, then other coated and uncoated carrots. The taste of coated carrots, especially for the treatment T_4 followed by T_2, the taste remained stable during the storage period rather unlike that of uncoated ones. Most people gave high scores to treatment T_4, followed by T_2. The minimum score was obtained by T_0^-. Similar findings were observed by Howard et al. (1995) that the taste of coated carrots has great scores rather than that of uncoated ones.

***Texture*:** The properties and surface appearance of the food are related to its texture. The primary characteristic that encompasses the food's sensory quality is texture. To ascertain the physical characteristics of the meal, texture is employed as a quality parameter.

Texture is generally described as smooth or rough, coarse or fine, and soft or hard. It was observed that the texture of coated carrots had high score than that of uncoated ones. During the 48-day storage study of carrots it was observed that coated carrots showed great texture compared to uncoated carrots. During 1st 15 days, it was observed that there is less change in texture. In the next 15 days, there was little change in the texture of coated carrots except for T_4 followed by T_2. After that in the remaining days texture of T_4 was much stable, followed by T_2, then other coated and uncoated carrots. The maximum scores were attained by T_2 followed by T_4. These two treatments provide a good finish and better results than those of uncoated ones. These made a fine texture of carrots and provide no white cast. The minimum result of texture was shown by T_0^- as it provides rough and course surface. An edible protein coating composed of soy protein isolate and whey protein concentrate. The results demonstrated by Ghavidal et al. (2013) showed that a protein-based formulation extends the shelf stability of apples while preserving their quality by preserving their color and texture. Fruits with coatings typically retain their moisture content and slow down the rate of deterioration, which prolongs their freshness and hard texture.

***Overall acceptability*:** Overall acceptability means the likeness and dislikeness of food on the basis of all features (Hussain et al., 2023). It was observed that both treatment and storage have a significant effect on all parameters. The score of acceptability decreases with increasing storage period. As the storage period increased, the acceptability score of all treatments decreased, but T_4, followed by T_2, showed great score of acceptability score than other treatments. Most of the

people gave a higher score of acceptability to T_4, followed by T_2. Minimum acceptability scored by T_{0-}.
(Cruz et al., 2015) noted similar results, suggesting that pears with an edible coating might keep their quality and have a longer shelf life. We looked at how consumers thought coated pears were a good product. According to their findings, applying an edible coating is a viable substitute for preserving fruits for an extended period of time.

DISCUSSION

In this investigation of proximate analysis, the moisture of tapioca powder was 9.75%, ash 0.37%, fiber 0.18%, protein 1.29%, fat 0.19% and NFE was 88.22%. A study showed similar results. Where starch from the cassava plant was extracted, and proximate analysis was done. The result showed that the moisture content was 9%, 0.31% ash, 0.20 fiber, 0.17% fat, 1.24% protein, and 88.23% NFE for tapioca (Ijioma et al., 2016). The ash content ranged between 0.1% and 0.7%, indicating that cassava grown in Tawau, Malaysia, or Semporna is mineral-rich. The total fiber content of tapioca is 2.09% and 2.38% (Rodriguez Sandoval et al., 2008).
The results of our study were of foaming capacity supported by these findings (Kaushal et al., 2012). Another study by Rasool et al. (2023) on the synthesis of edible coating made by natural gums showed that the value of foaming capacity for tragacanth gum was 4.32%. One more study showed the value of water chestnut, which was 20.54% and 20.58% for two different concentrations of water chestnut powder (Mahnoor et al., 2024).
The results of water holding capacity were supported by another study, which indicated that tapioca powder's water holding capacity increased by heating due to swelling of starch molecules, and oil holding capacity decreased by heating due to physical and chemical changes (Sangadji et al., 2024).
A current study aligns with the weight loss of carrots during storage. Weight loss during storage indicated a decline in quality, which leads to customer rejection. Because of their moisture-retention qualities, edible coatings can prevent fruits and vegetables from drying out, extending the shelf life of minimally processed products (Han et al., 2014).
The results of firmness reduction align with Kalsoom et al. (2025). The results demonstrated that there was a reduction in firmness of tomatoes at the 20th day of the storage period (Kalsoom et al., 2025). Our results related to antioxidant reduction are closely relevant to that study (Haq et al., 2017).
The results of the taste of coated carrots align with findings observed by Howard et al. (1995) that the taste of coated carrots has great scores rather than that of uncoated ones.

Conclusion: This study aims to analyze the impact of tapioca and guar gum-based coating on carrots' (*Daucus carota*) shelf life and quality. Carrots were stored at refrigeration temperature for 48 days. Different analysis of tapioca powder as well as carrot juice was done. The moisture content of tapioca powder was calculated at around 9.72%, ash 0.34%, fiber 0.15%, fat 0.19%, protein 1.27%, and NFE 88.2%. The water holding capacity of tapioca powder was 2.38% without heating and 3.07% with heating. The oil holding capacity of tapioca powder was 2.40% without heating and 1.72% with heating. Similarly, the viscosity and foaming capacity of tapioca powder were 3.29% and 7.36% respectively. The mean values for weight loss and decay percentage showed significant differences throughout the storage period. Less weight loss and decay percentage was shown by treatment T_4 (5.99%), (2.243%), followed by T_2 (6.416%), (2.563%). Firmness, juice yield, and titratable acidity also showed significant results. Maximum values were shown by T_4 for firmness (3067N), for juice yield (105.0%), and for acidity (0.248%), followed by T_2 (3065N), (104.4%), (0.246%), respectively. Similarly, pH, TSS, antioxidants, and phenolic contents decrease with the passage of time. Minimum values were shown by T_4 for pH (6.202), for TSS (8.5◦Brix), for anti-oxidants (16.07ug/g/g/g), for phenolic contents (39.61 mg GAE/g), followed by T_2 (6.203), (8.565◦Brix), (16.08ug/g), (39.63 mg GAE/g), respectively.

Declarations: Ethics approval and consent to participate. No animal or human study was involved in this work; however, for the sensory evaluation study, informed consent was obtained from all individual participants included in the study (all above 18 years of age). This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of the University of Sargodha, Sargodha, Pakistan, with order no.

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